A Watershed-Scale Groundwater-Land-Surface Model

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Introduction

Land Surface Models

- Ignore deep ground-water and lateral water flow

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Groundwater models

- Relatively simple evapo-transpiration scheme

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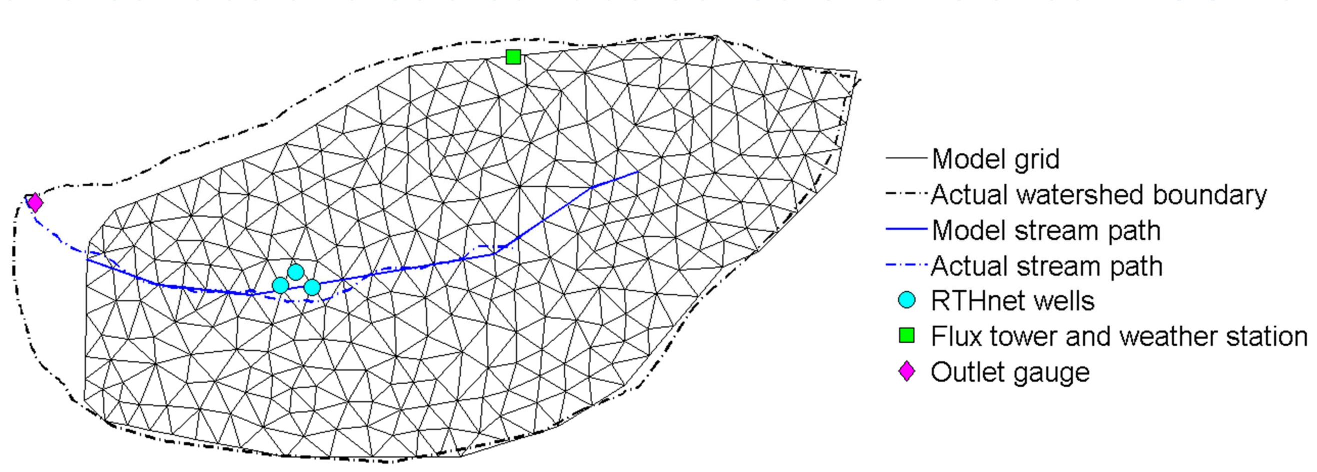
Coupled models of groundwater and land surface

- may yield significant improvements in short-term climate and flood/drought forecasting

- Goals:
  - Develop a fully-coupled groundwater-land-surface model
  - Comprehensively evaluate hydrologic and surface energy balance predictions with high-frequency data at a measurement-rich site

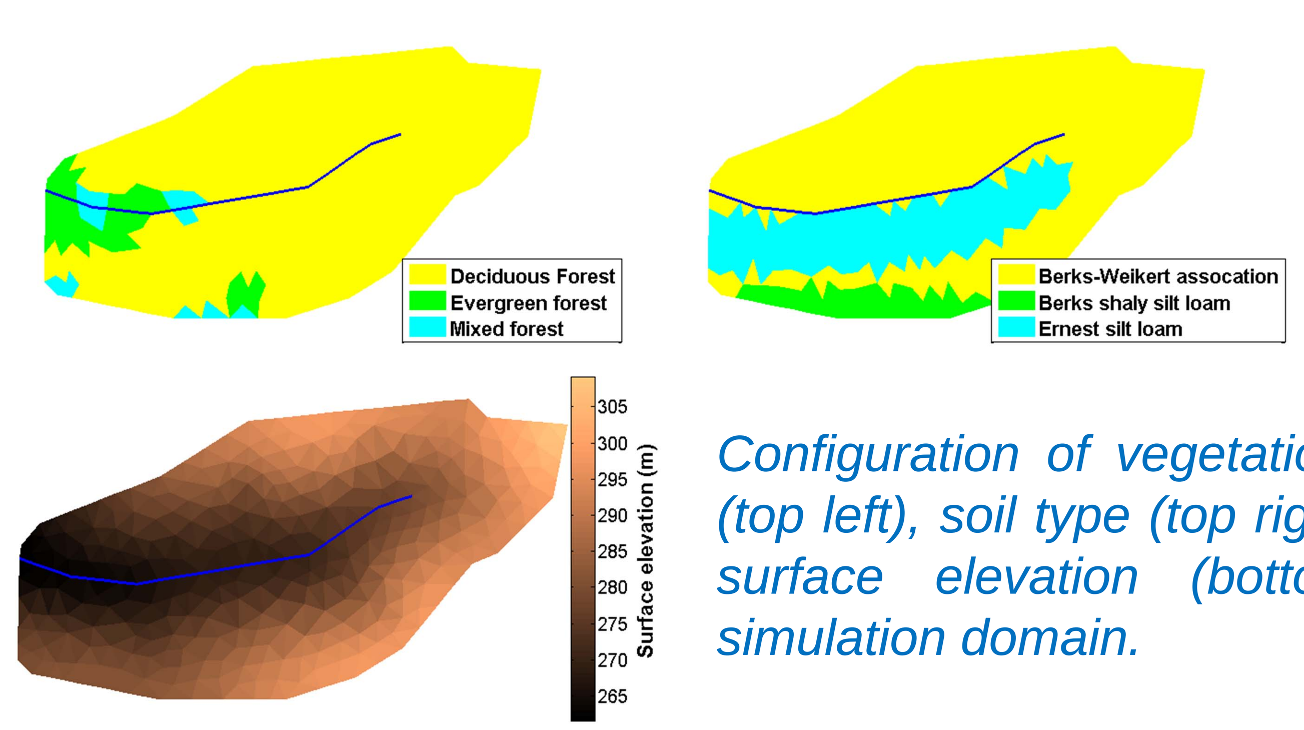
Model and data

- A land-surface module is incorporated into the Penn State Integrated Hydrologic Model 2.0 (PIHM 2.0)
  - Fully coupled surface water, groundwater, and land-surface components
  - Land-surface scheme is mainly adapted from the Noah LSM
- Susquehanna/Shale Hills Observatory (SSHO) in central Pennsylvania (0.08 km^2)
  - Small-scale V-shaped catchment with 1st order stream
  - Real Time Hydrologic monitoring network (RTHnet) with an array of land-surface and sub-surface sensors is installed in SSHO



Grid setting for SSHO model domain.

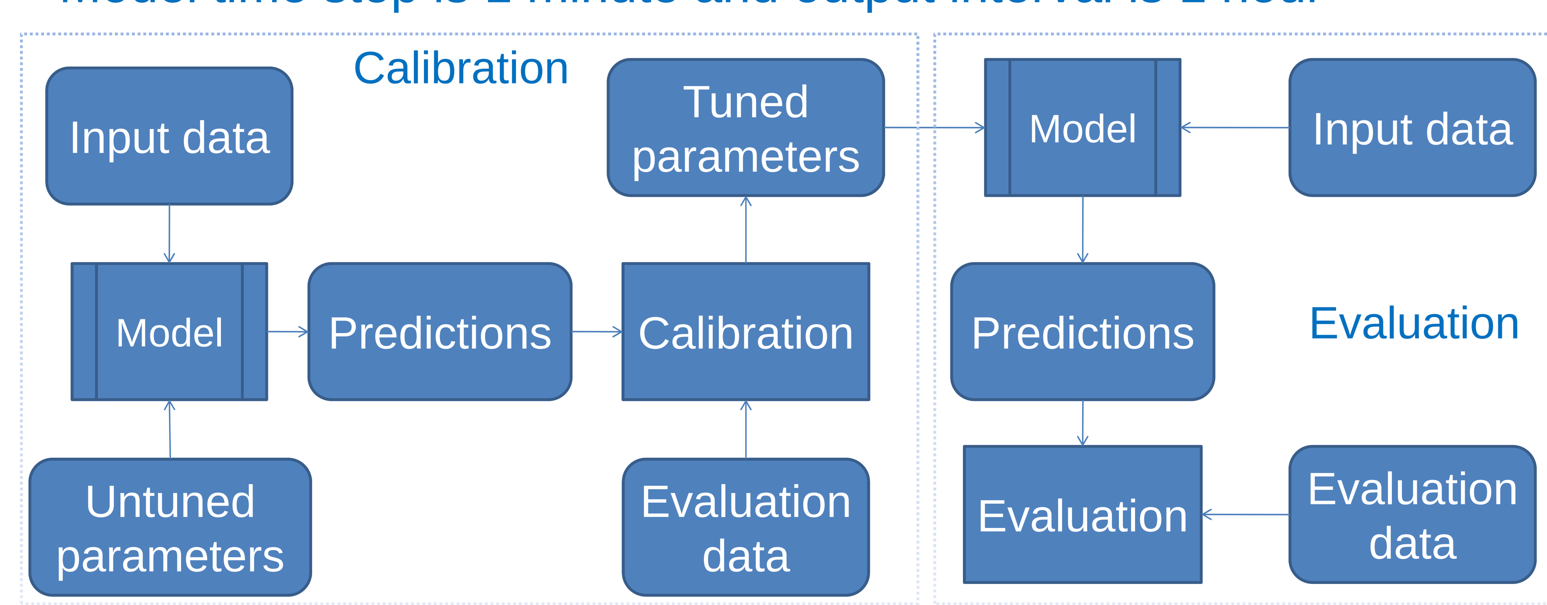
- Model domain
  - Total size 0.076 km^2 with a triangular irregular network of 571 grids and 318 nodes
  - River channel represented by 21 river segments
  - Uniform bedrock depth (2 m)



Configuration of vegetation type (top left), soil type (top right) and surface elevation (bottom) of simulation domain.

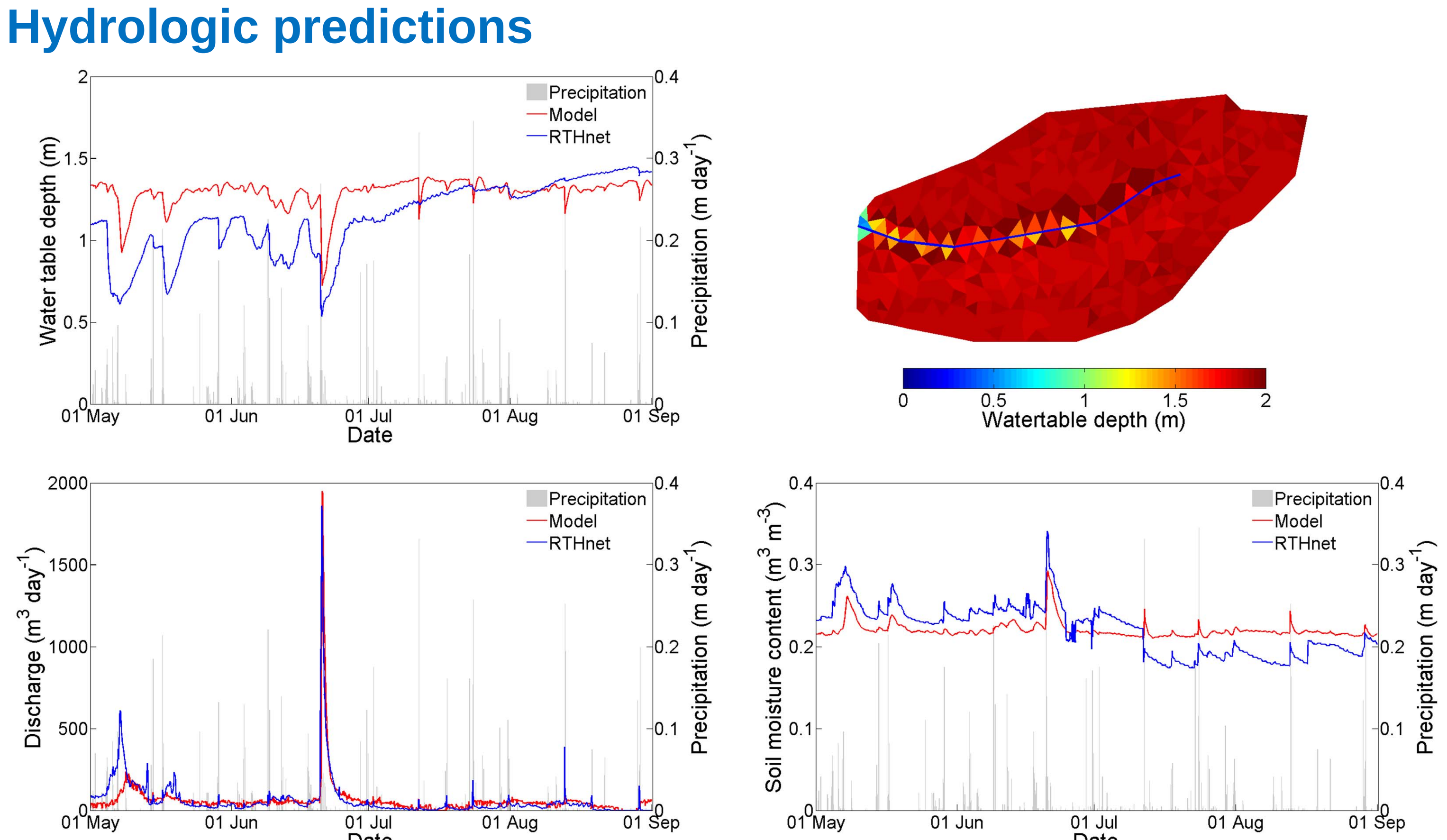
	Input data	Source
Input data	Surface elevation	Field survey
	Soil map and parameters	SSURGO
	Vegetation cover and parameters	NLCD 2001
	Precipitation, air temperature, and RH	RTHnet
	10-m wind speed, downward longwave radiation, downward solar radiation, and surface pressure	NARR
	LAI, roughness length	NLCD 2001
Evaluation data	Discharge	RTHnet outlet gauge
	Water table depth and soil moisture content	RTHnet wells
	Surface heat fluxes and net radiation	RTHnet flux tower

- Simulation from 0000 UTC 01 May to 0000 UTC 01 Sep 2009
- Model is spun-up by running from 01 May 2008 to 01 May 2009
- Model is calibrated with in-situ measurements using "trial and error" strategy
- Model time step is 1 minute and output interval is 1 hour



Results

Hydrologic predictions

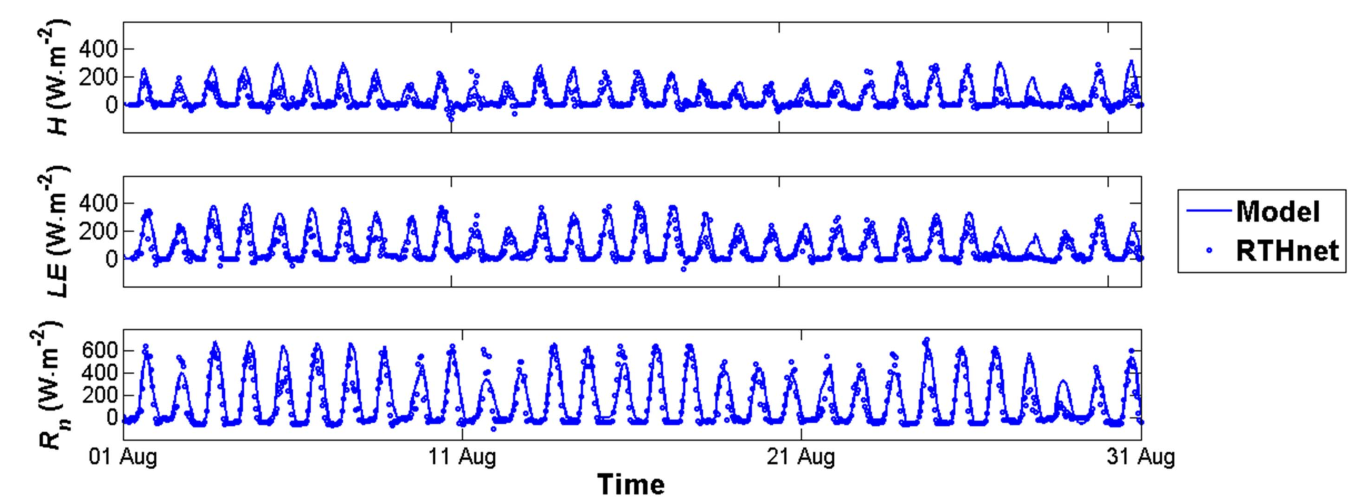


Comparison of hourly water table depth (top left), discharge (bottom left), soil moisture content (bottom right) between model simulation and RTHnet measurements, and map of water table depth averaged over entire simulation period (top right)

- Model captures temporal patterns, but tends to underestimate amplitudes in water table depth and soil moisture variation
- Model reproduces flood in June and low flow situations

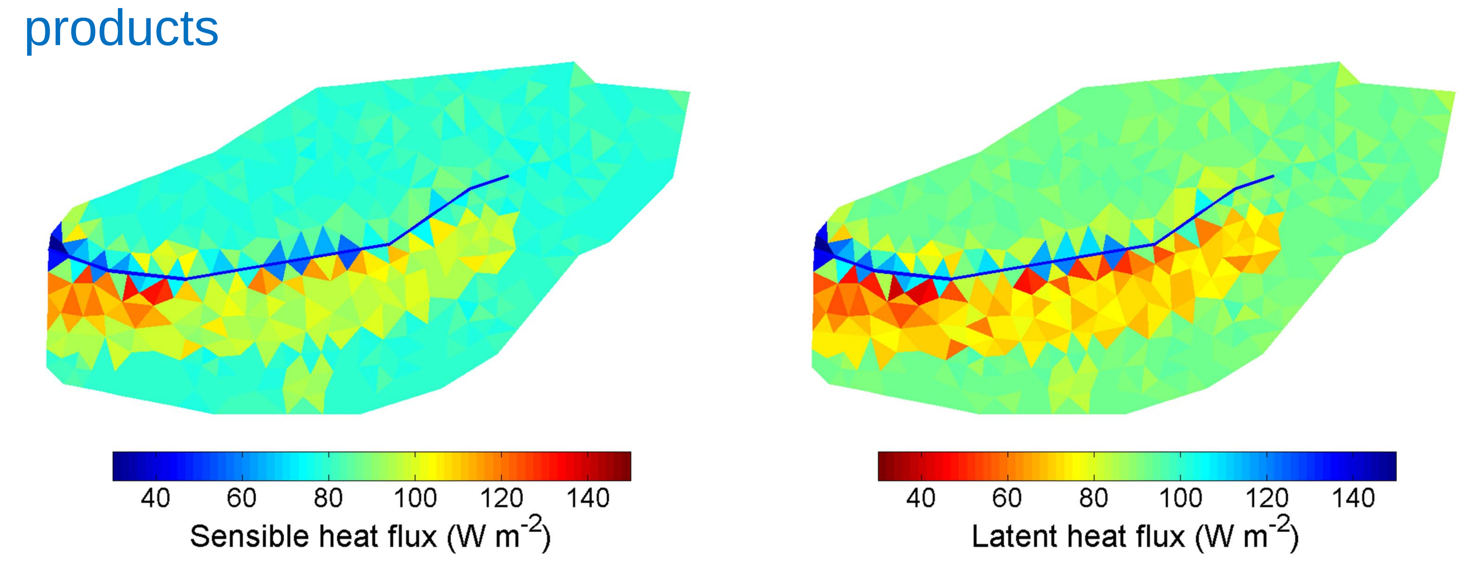
- Results could be improved by
  - applying better optimization method
  - using locally measured bedrock depth, soil map and parameters, and vegetation cover and parameters
  - and adopting better physics

Surface energy balance (SEB) predictions

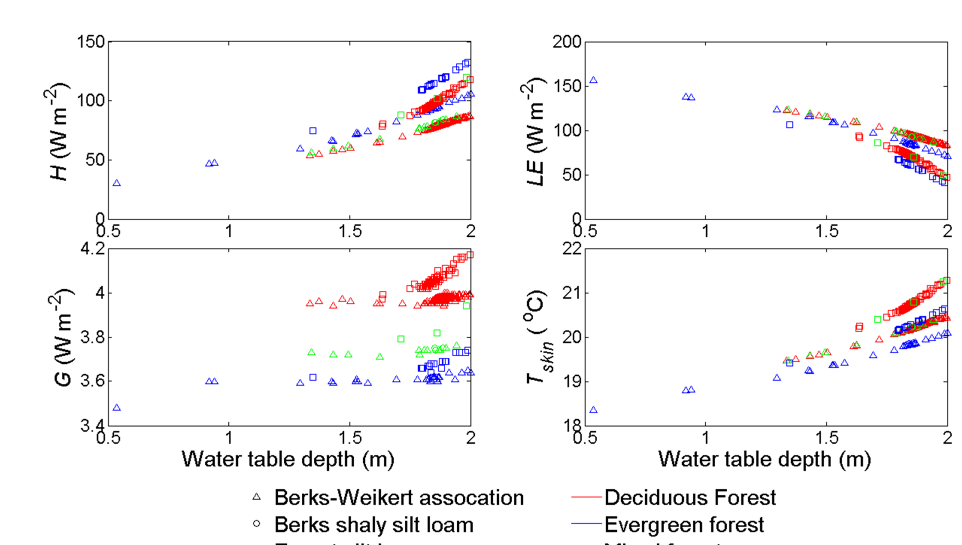


Comparison of sensible heat flux (H), latent heat flux (LE), and net radiation (R_n) (from top to bottom) between model and RTHnet flux tower from 01 Aug to 01 Sep 2009

- Model captures temporal variation of surface heat fluxes reasonably well
- Model performance is limited by quality of NARR radiation products



Map of sensible heat flux (left) and latent heat fluxes (right) averaged over entire simulation period



Simulated sensible heat flux, latent heat flux, ground heat flux (G), and surface skin temperature (T_{skin}) as functions of water table depth

- Land surface variables are affected by topography, soil type, and landcover type, and are correlated to groundwater table

Future Work

- Questions to answer:
  - How does land-surface affect hydrologic predictions?
  - How does groundwater improve SEB prediction?
- Incorporate data assimilation module into model to assimilate in-situ measurements and optimize model parameters
- Study subsurface-land-surface interaction
- Test model on different spatial scales
- Evaluate model on flood/drought prediction at scales up to the Juniata River Basin (~8800 km^2)